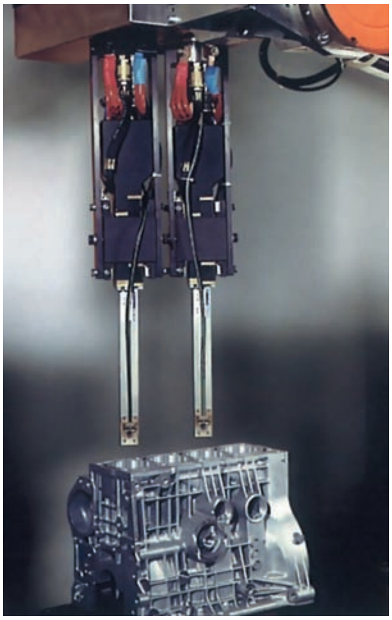
Beyond measurements

SUME*Bore*™ is a holistic coating solution that—depending on the application area—gives the cylinder running surfaces of internal combustion engines specific properties. This can mean, for example, lower friction and a higher resistance to corrosion. The flow specialists at Sulzer Innotec support the application process with the help of computer-assisted flow simulations, enabling the visualization and verification of the flow situations in a cylinder during coating.

Sulzer Metco offers not only products but also complete solution packages to its customers. This added offering allows the customer to apply the coating technology simply and efficiently. SUME*Bore*™ is a holistic coating solution that—depending on the application area—gives the cylinder running surfaces of internal combustion engines specific properties.

Solid lubricants

Solid lubricants can be integrated into the coating by using powders based on iron and carbon. The coating, which is applied through thermal spraying, has the desired light porosity, while the engine oil in the spray pores reduces friction—in particular during a cold start. The coating is normally applied using the RotaPlasma™ spray process—a subprocess of the Sume*Bore* coating soluton. In doing this, a rotating, bar-shaped, and water-cooled Sulzer Metco F210 plasma gun is inserted into the cylinder that is to be coated 1. Plasma guns using electrical arcs are used to heat a gas or gas mixture to more than 10 000 °C and to accelerate it. The added powder melts in flight, and the liquid particles create the desired coating when they impact the surface of the workpiece. Depending on the bore diameter of the cylinder, a varying number of processing steps will have to be carried out in order to achieve the desired coating thickness of approximately 200 µm. Because the roughness level is around 50 µm, the coating will be honed in a subsequent working process. The definitive coating thickness that is finally achieved is around 120 µm.



1 Coating a cast-aluminum motor block with a wear-resistant layer.

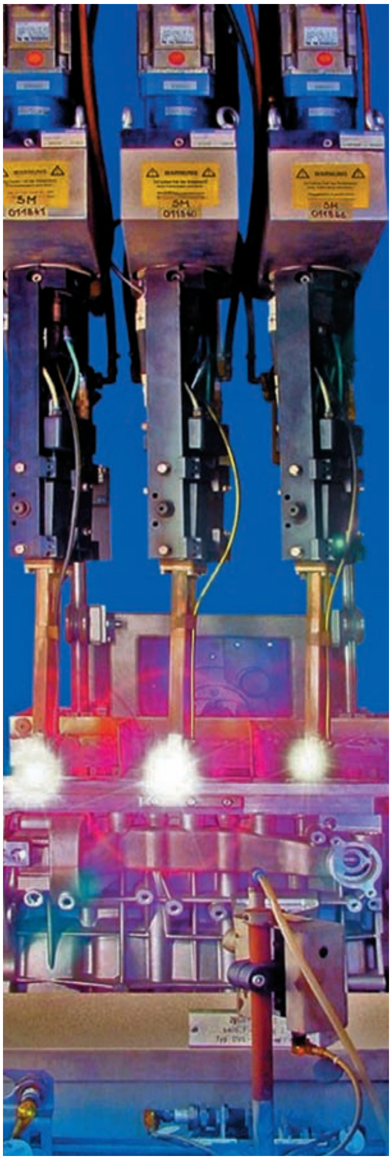
Temperatures of more than 10 000 °C

Because the plasma plume reaches temperatures of more than 10 000 °C 2 and the geometrical conditions within a cylinder bore are tightly dimensioned, the workpiece will be subjected to high thermal stresses. Bores for adding compressed air are made on the rear side of the F210 burner; that way, the surfaces facing the plasma cool down directly following the coating. Compressed air is also used to focus the plasma plume optimally during the processing. An additional nozzle (shroud gas) is also located above the plasma nozzle, and serves to cool the components with cold gas (mainly argon) and shield them from the hot plasma flow 3. To ensure that the unmolten powder (overspray) causes as few flaws as possible in the coating, an additional axial airflow is forced through the cylinder bore and carries away any excess powder.

The goal of the simulation was to visualize the flow inside the cylinder and to investigate if the time and material efforts could be further reduced for the RotaPlasma spray process.

Numerical flow simulation

In order to continuously improve the process, the relationships of the complex



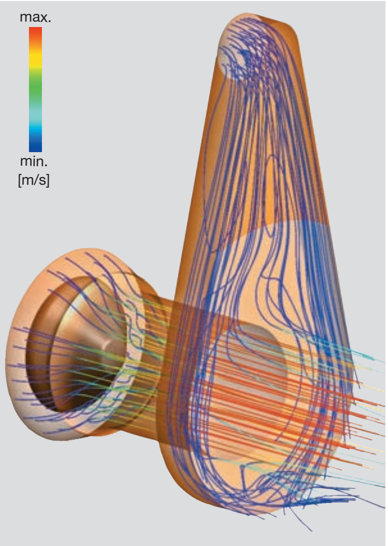
2 Plasmas during the coating process.

flows have to be analyzed during the operation. However, the kinetics and the high temperatures of the process make the use of measurement technology almost impossible. In order to increase our understanding of the process and to better understand the flow relationships in the operation, numerical flow analyses (computational fluid dynamics, CFD) were carried out. CFD development is so advanced that even complex flows can be mapped virtually. Ionized gas behaves in different ways depending on the level of ionization, and its behavior requires the tabular storage in the simulation program of the material data correspondent to temperature (up to 30 000 °C) and pressure (up to 10 atm). With the help of interpolation functions, the exact gas properties can be taken into consideration. The possibility of a direct numerical coupling between the flow simulation and the electromagnetic system (magnetohydrodynamics, MHD) was deliberately ignored in this case, because the focus was placed on the flow in the cylinder.

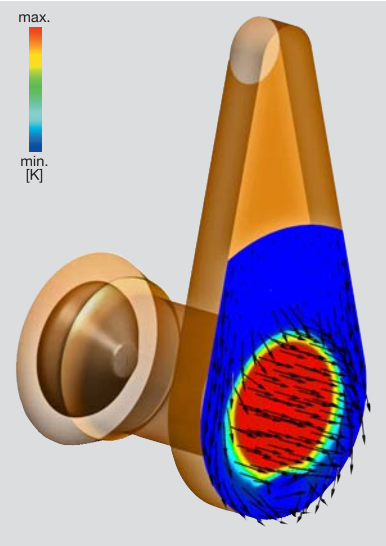
Two-stage modeling

To improve the convergence of the numerical analyses, the setup was split into two simulations. In a first step, the hot nozzle flow was represented by means of an artificial heat source 4. About 9 kWs are necessary in order to reach the maximum gas temperatures of 14 000 °C. The influence of the cold gas nozzle was also taken into account in this first part of the simulation. The calculated flow state at the nozzle outlet (values for velocity, temperature, and turbulence) was then exported locally and was set into the simulation of the cylinder flow as an inlet boundary. In order to minimize the outlay for the simulation and the associated computer time, the complete computational domain was reproduced as rotating, and the cylinder wall was stationary. This setup allowed a stationary assessment to be made of the flow conditions in the bore.

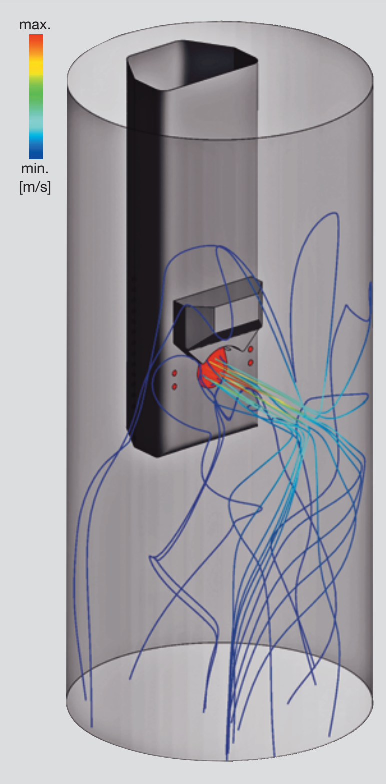
With the help of this CFD analysis, it was possible to visualize the flow situation within the cylinder bore during the



3 An additional cooling-gas nozzle is also located above the plasma nozzle, to shield the components from the hot plasma flow. The illustration shows the stream lines.



4 Simulation of the hot-nozzle and cold-gas flow. Cross section at the nozzle outlet, with visualization of the temperature (colors) and velocity (arrows).



5 Visualization of the flow during the coating process: 3D view of the stream lines from the nozzle.

process 5 6. Spraying trials carried out beforehand had indicated the influence of the compressed air pressure on the resulting quality of the coating. For this reason, the simulations were carried out with two widely differing pressures.

If the compressed air pressure is too high, the area of influence of the cold air moves forward along the circumference of the cylinder wall towards the coating zone and interacts directly with the plasma plume where it impacts the cylinder wall. This leads to a strong instability of the flow conditions during the coating and can affect the quality of the final coating. It can even lead to particles that were already molten in the plasma becoming solid once again before impacting the wall, thereby causing flaws in the coating.

Increased process expertise

The results achieved have led to an increase in process know-how and to an adaptation of the individual process parameters. Geometric optimizations to the F210 gun were not carried out. However, the knowledge that was gained will flow into the development of new products.

With increasing computational power and increasingly accurate models, numeric flow simulation has developed into a very important design tool in the last decade and has become virtually irreplaceable in the development process of Sulzer products.

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6 Visualization of the flow during the coating process.